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Science writers: How they keep up

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DEDICATION

I dedicate this thesis to my family: my mom, Shauna, my dad, Jim, my sister, Brittany, and my brother, Bryce, for all their support and encouragement while writing this thesis.

I also dedicate this to my closest friends Erica and Laura for their encouragement, friendship, understanding and support.

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ABSTRACT

This research examines how science communicators understand the fields that they write about. This thesis looks at how science communicators become aware of (or “learn about”) the increasingly specialized subfields of science. The thesis also examines how science communicators educate themselves (or “keep up”) with ongoing changes in the field. The study, which integrated a survey with 161 participants and five in-depth interviews, also uncovered the demographics of science communicators, as well as the pressures they face on-the-job. According to the study’s results, there are no ineffective methods for learning about or keeping up with science, indicating that science communicators are using everything at their disposal to become aware of and remain educated about science. Another area looked at was a potential reflection of the relationship between scientists and communicators based on how easy/difficult it was for communicators to get in contact with scientists, and how eager/willing they were to talk to communicators. The findings show that scientist and communicators seem to have positive relationships with each other. These findings all have significance because they can be used by science communicators to improve practices.

CHAPTER 1

INTRODUCTION

The advancement of society depends on and is driven, in part, by scientific and technological advancements (Maier, Rothmund, Retzbach, Otto & Besley 2014). These advancements can lead to new practices in medical fields, cause new products/technologies to be developed or can influence the adoption of laws/regulations. Scientific research is growing faster and faster as it becomes more interdisciplinary, privately funded and global (Amend & Secko, 2010). The growth rate of science publications averages 4.7% annually (Larsen & Von Ins, 2010). Additionally, there were an estimated 250,000 science-related journals in 2004, 24,000 of which were peer-reviewed (Larsen & Von Ins, 2010). Twelve years later, the number of these journals has likely grown even larger. Science communication is essential to disseminate information and to generate public interest and debates in and about science.

Science communicators are professionals who use skills, dialogue and all forms of media to raise awareness, to form opinion(s), to create public interest and to promote understanding of science for a non-scientist audience (Poliakoff & Webb, 2007). Science communicators can have backgrounds in a communication field or be anyone who tries to communicate science-related information to non-specialist or non-scientist audiences. Science writers are often described as "translators" because the highly technical "language" of science has to be "translated" for those outside the field (Dunwoody, 1979). Within the context of this thesis, "science communicators" refer to those who attempt to disseminate and/or explain science to non-specialists or non-scientist audiences.

The role of science communicators is vital as science sits at the center of most major issues that the global society is facing, and will face, such as: economic productivity, sustainable development and health (Poliakoff & Webb, 2007). Because of how relevant science is to many public topics, the scientific community has an obligation to create and maintain links with the general public, either as individuals or through science communicators (Poliakoff & Webb, 2007).

This translation role stands vital because most non-scientists do not understand science well. A 2001 National Science Foundation study showed that almost half of America's population doesn't know that it takes one year for the earth to revolve around the sun. If the audience doesn't know even basic information like this, it means that communicators must work even harder to "translate" science into even simpler language. The problem here is twofold: First, if people can't remember simple facts, how can they remember anything complex and/or highly detailed? Second, science can only be simplified so much before it no longer resembles the original science.

Despite the lack of knowledge identified by the general public, there is an interest in science and technology stories. Twenty percent of Americans preferred science and technology stories – beating almost any other topic, including politics (Van Eperen, Marincola & Strohm, 2010). In a 2014 Pew Research Center survey (the General Public Science Survey), 37 percent of respondents said they enjoyed keeping up with science news "a lot," while 35 percent said they "somewhat" enjoyed keeping up with science news. Only 18 percent said they didn't enjoy it much, and 9 percent said they didn't enjoy it at all.

There is clearly a demand for science stories from the public, even if they are not always "scientifically literate" to what some may consider an "acceptable degree." Because this demand exists, it presents an opportunity for scientists and science communicators to fulfill.

Geller, G., Bernhardt, B. A., Gardner, M., Rodgers, J., & Holtzman (2005) says that mass media is the public's best source of information about science. For most people, the press is often their only means of understanding and learning about what's happening in science and technical fields, as well as the implications and potential consequences of these advances. Science communication informs people about what's happening in science and places that activity into a larger context (Treise & Weigold, 2002). This allows the public to effectively (or knowledgeably) form opinions and make decisions. It also aids them in decision making – particularly avoiding "pseudoscience" – information that seems like it is scientific, but isn't, or is only somewhat scientific with skewed or misinterpreted results (Treise & Weigold, 2002). It's also important because communicators are also influenced by their audience. Outlets with more educated readers may cover science and technology stories in greater depth, while outlets with less educated readers may cover it less (Weigold, 2001). Currently, there is also some concern that science communication is being taken up more frequently by special interest groups who distort or withhold the truth – meaning it is more vital than ever for scientists to communicate with laypeople (Leach, 2013). Scientists should consider forming better communication with the public and public leaders because advocates, who lack objectivity, may fill the gap in knowledge that scientists are reluctant to fill (Safina, 2012). This misunderstanding between the scientific and public spheres can be alleviated, in part, by science communicators, who have the role of translating science into a form that is understandable by the general public. Science changes so quickly that those who only have basic (or no) education about a science, are often unable to keep up with or make sense of changes (Polman, Newman, Saul, & Farrar, 2014).

Given the sheer volume of new discoveries that science communicators must translate to the general public, it is important then to understand how science communicators "learn about" and “keep up” with and learn about science and technology. Learning about science is the process by which a communicator becomes *aware* of a topic, idea or new discovery within science. Keeping up is the *ongoing* process by which a communicator becomes educated enough about a scientific field to effectively communicate it to the public.

Currently, there are few studies available on the methods and resources that science communicators use to learn about and/or keep up with new research, discoveries and developments in science. Prior research has looked the relationship between communicators and the public, and communicators and scientists (Treise & Weigold, 2002; Geller et al., 2005; Weigold, 2007; Leach, 2013; Autzen, 2014; Maier et al., 2014). However, research has largely ignored how science communicators become educated enough to understand and communicate science to a non-scientist audience. The dearth in the literature raises the question: How do communicators become educated enough – and then remain well educated enough – to effectively and accurately write a story about the science in question? The goal of this research is answer that question and offer suggestions and advice to improve the field of science communication for the future. More specifically, this research looks at three main points: the current demographics of science communicators, how communicators learn about and keep up with science, and what pressures may influence science communication.

To examine the central issue of how science communicators learn about and keep up with science topics, the literature review traces the history of science communication, which provides background and context on how practitioners construct knowledge about science. The relationship(s) between scientists and communicators is also explored because scientists are often one of the few (if not the only) source of knowledge about advances and discoveries in the field. Though some scientists may act in roles as communicators, it is worth looking at the relationship between scientists and communicators as they regularly come in contact with each other, shaping how science is communicated. To examine the production of science knowledge by science communicators, this thesis integrates the theoretical concept of gatekeeping. This theory fits with the research because, for this research, there are considered to be three gates; the scientists, the communicator's ability to understand science, and what the communicator presents to the public. Lastly, science literacy will be addressed, as the ultimate goal of science communication is to disseminate science to non-specialist audiences, which, to some degree, may influence public knowledge of science.

The study's methodology advances arguments for using a survey and interviews with communicators from various fields (government, university, traditional media, freelancer and medicine) to gain insights about practice. It also outlines the protocol for both the survey and interview, while also integrating the use of grounded theory. The data findings section highlights the study's key findings, including insights into the demographics, learning abilities and pressures inherent in science communication. In summary, this research provides a clearer understanding of how science communicators learn about and keep up with science, in order to provide suggestions for best practices that communicators can employ to improve the quality of science communication overall. The study's significance rests in finding the most efficient and effective methods of learning about and keeping up with science, which can be used by practitioners to improve the field of science communication for the future.

CHAPTER 2

LITERATURE REVIEW

Science communication: An evolving field

It is difficult to determine the exact beginning of science communication. It could start in the 1800s with works such as Charles Darwin's *Origin of Species* and other similar attempts by scientists to communicate their findings with the public. Or one could consider the works of ancient philosophers, alchemists, inventors, explorers and others in communicating their understanding and discoveries as a form of science communication (Leach, 2013). Leach (2013) proposes three possible beginnings for science communication. The oldest is ancient philosophers, scientists and inventors communicating their discoveries with others. The second is the creation of the actual profession of "science communicators" during and after World War II. The third possible beginning is based in the creation and management of information about science. In the 1950s, the academic papers we have today were created. Since then, academic articles have become more specialized, obscure, cryptic and more difficult for laypeople to understand. Science communicators were hired to help junior researchers write and understand academic papers, in addition to helping write proposals and grants (Leach, 2013). This led to the creation of the National Association of Science Writers, as well as the creation of similar organizations, focused on advancing the practice of science writing and communication (Dunwoody, 1979).

Whenever it started, the peak of science coverage, at least for traditional media such as newspapers, radio and television, was during World War II and the Cold War (Weigold, 2007). Technological and scientific advancement were seen, at least in the United States, as important in order to secure victory (Weigold, 2001). In addition, Sputnik's launch in 1957 increased public interest in science (Weigold, 2001). More regular science writers were brought onto newspapers during the 1960s to cover the lunar trips and landings (Dunwoody, 1979).

By 1996, almost 40 years after Sputnik's launch, there were about 122,000 reporters and journalists (Weigold, 2001). Less than one percent of these communicators (about 600 – 800) were estimated to be science and medical writers/reporters (Weigold, 2001). In 2002, half the newspapers and less than 10 percent of television stations in the United States employed one or more specialized science communicators (Valenti & Tavana, 2005). Despite the low numbers of science communicators, the knowledge the public has about science generally comes from mass media (Valenti, 2005). Though science coverage in traditional media is declining, other platforms for science communication are on the rise and there are many types of science communicators as a result.

Types of science communicators

Science communicators cover a broad spectrum of professions, ranging from journalists to public relations (PR) specialists to freelancers to in-house writers. While some larger news organizations will have specialized reporters who focus on predominantly science-based topics, science is largely seen as a niche or specialty area by most news organizations today. Journalists largely rely on peer-reviewed articles to judge how accurate or trustworthy a source is (Treise & Weigold, 2002). The new issue facing these communicators is the appearance of independently-run science web sites that may or may not have extensive peer-review processes. This makes it more difficult for science communicators to pick out what's important and assess valid and reliable science (Treise & Weigold, 2002). Other journalistic sectors of science communication have shown growth. Niche media (a type of media that focuses on one topic, area or audience rather than targeting a mass audience) has been on the rise since the advent of the Internet (Dimmick et al., 2004). In the context of science communication, these sources compete with traditional, and usually less biased media, by appealing to the consumer's satisfaction (Dimmick, 2004).

Freelance writing has been a growing segment of the industry, and often replacing the role traditionally held by journalists, since the early 2000's because employers save money by contracting freelancers rather than hiring full-time employees (Brady, 2011). In addition, it is sometimes easier to gain corporate approval for a part-time contract rather than a full-time one (Brady, 2011). Finally, businesses that are based on project-based structures often have difficulty with making long-term plans, including necessary employment (Brady, 2011). Freelance science writers, however, are facing challenges in selling their science writing. Due to shrinking newsroom staffs and budgets, and increased pressure to put out more content, newspapers and online media platforms rely on reposting science-related press releases verbatim, rather than keeping in-house writers or hiring freelancers (Autzen, 2014).

Beyond news, science communicators are increasingly hired or expected to work in PR capacities within private companies and research institutions (Weigold, 2001; Lynch, Bennett, Luntz, Toy, & Vanbenschoten, 2014). PR practitioners have to not only write about the science done at their organization; they also have to catch the attention of journalists, hoping that they positively reinforce the image the organization. As a result, PR has had to become similar to science journalism, in that it must frame science in a way non-scientists can understand it (Lynch et al., 2014). PR practitioners regularly produce a large variety of material for many audiences: stockholders, laymen, employees, outside media or magazine subscribers (Weigold, 2001). Public relations practitioners have a variety of options for putting their message out, such as:

speeches/writing, conferences/exhibitions, sponsorship/promotions, advertising and lobbying (Jasinski, 2010). In the field of science communication, one example of a public relations tool is EurekAlert Science News, a wire service run by the American Association for the Advancement of Science (AAAS) (Autzen, 2014). In 2013, more than 20,000 press releases were posted to the site, half of which were from universities. In many cases, science communicators adapted their press releases so the media would be more likely to pick them up (Autzen, 2014). Often, news media would repost the press releases verbatim (Autzen, 2014). This “copy and paste” method of journalism is concerning to some that think it is causing “watchdog journalism” in the sciences to decline (Autzen, 2014). Other PR communicators, particularly those working on behalf of advocacy organizations, may frame science communication to change the appeal of some policies or to persuade individuals to take a certain opinion – regardless of how accurate or inaccurate the science they bring up is (Hutchings & Stenseth, 2016).

Given the changing landscape of practitioners in the field of science communication, there are many concerns about how science communication will fare in the future. Communicators’ job security, especially that of journalists, is being eroded. As a result of downsizings within media outlets, communicators have to cover more and more (Lynch et al., 2014). Consequently, the power balance between science PR and science journalism is shifting in favor of PR (Lynch et al., 2014).

Science communication as a field has changed drastically over the years, and is likely to continue changing with new technologies and social/political/ideological shifts related to science. One vital area to look at to fully understand science communicators is their relationship(s) with scientists.

Relationships between scientists and science communicators

The relationship between scientists and science communicators is complex. Scientists generally view journalists in a negative light while seeing themselves, and other scientists, in a more positive light (Weigold, 2001). Conversely, research found that the relationships between science writers and scientists is generally positive and that communicators generally expressed interest in creating and maintaining positive relationships with scientists (Geller et al., 2005; Peters, 2013). Most research since the 1970s has looked at the negative aspects and perceptions of the relationship between scientists and communicators, a view that has dominated the literature since then (Peters, 2013). A large portion of scientists willingly interact with communicators and generally have positive relationships with them, so they get along rather well (Peters, 2013). Most scientists think they have benefited from visibility in the media, encouraging them to continue remaining in contact with them (Peters, 2013).

Nevertheless, incorrect or inaccurate information about science in media has been previously attributed to poor communication between scientists and science communicators (Geller et al., 2005). There are several reasons offered for this poor communication. Some science communicators don't see themselves as neutral disseminators of information. Instead, they usually want to put out information that non-scientists need to properly reflect on science (Maier et al., 2014; Geller et al., 2005). Public relations practitioners communicate the research and will also try to tell (or control) the institution's story and/or maintain/control its image (Autzen, 2014). Scientists have to be flexible and allow the possibility of hypotheses and/or theories being disproven by new information, technology or experiments (Weigold, 2001). This leads to tentative suggestions about the implications of the research, rather than the concrete claims communicators – particularly journalists -- are looking for (Weigold, 2001).

Communicators, on the other hand, have often viewed scientists as narrowly focused and (intentionally or not) obscure in their communication (Weigold, 2001). Scientists work with tiny pieces of a larger whole, which sometimes makes it difficult for them to explain why what they're doing is important, without giving lots and lots of relevant information that communicators may not be interested in or have the time/space to cover (Weigold, 2001). This creates tension because science communicators may find that controversy, violence or scandals are what sells and science stories. Without these elements, such stories may find it hard to compete for space or time in media coverage.

Scientists see communication with non-scientists as secondary to their research (Hull, 1987). While some scientists will use media to enhance their careers (Hull, 1987; Rinaldi, 2012), scientists who reach out to media in a genuine attempt to educate the public may, in some cases, face criticism, backlash, and/or accusations of enhancing their reputations by seeking public coverage of their work (Hull, 1987). When contacted and used as a source, they will often be as technical as possible to avoid being misquoted or having their research misrepresented (Weigold, 2001). When the discoveries are disproven or wrong, the negative press can harm careers and/or the public's perception of, and trust in, science (Rinaldi, 2012). This engagement also harms everyone involved from the researchers to the communicators, stakeholders, institutions and possibly the public (Rinaldi, 2012). Science communicators, especially journalists, have also been criticized for not reporting critically, not focusing on the scientific progress or economic benefits of research in favor of results, for having bias towards 'positive' messages, and for creating unnecessary hype (Amend & Secko, 2010).

To resolve these issues, Van Eperen et al. et al. (2010) offer several reasons for scientists to work more closely with science communicators. First, Van Eperen et al. claim that research covered by communicators or large media organizations is more likely to get noticed more than those that aren't. Second, Van Eperen et al. et al. identify that researchers who can communicate the importance and necessity of their work to the media are more likely to receive grant applications. Articles picked up by the press can also lead to research being picked up in other disciplines, creating more opportunities for new scientific breakthroughs. Van Eperen et al. also suggests that researchers speak to public relations personnel in their company, as these individuals usually have experience in dealing with outside media and can prepare researchers to communicate better.

There are, however, some similarities between the ways that science communicators and scientists approach their work. Scientists see themselves as educators and often think the media's role should be education as well (Geller et al., 2005). Science communicators see their role as primarily informers, and secondarily as educators, though some (both scientists and communicators) state that doing both would be best. Scientists and science communicators also both see their responsibilities as sharing accurate information or disseminating information to further advance their fields (Geller et al., 2005; Weigold, 2001). Scientists also seem to recognize and account for the differences between inner (scientific) and outer (public) communication, and will change how they talk about science as best as possible to address those differences, similar to how communicators will (Peters, 2013).

Regardless of where the communicator is coming from, they can provide several benefits for scientists and institutions that work with them (or ones they work for). Scientists, research institutions and universities need good relationships with science communicators to increase science literacy and to show politicians (and/or other possible sponsors) that science has value/is worth the time and monetary investment (Jasinski, 2010). Positive engagement can result in increased publicity and positive relations/reputations, increased science literacy, increased money for research and/or development and increased opportunities for additional research or marketing/commercialization (Jasinski, 2010). Scientists have also recognized the benefits of active communication with communicators and having their research presented to the public in mass media – which many organizations and universities encourage (Peters, 2013).

In the process of communicating science to the public, scientists may be the only source of information on research or findings that a communicator wants to understand and communicate. If a scientist's relationship with communicators is negative, it makes it harder (if not impossible) for communicators to acquire the information needed. If the scientist is hindered by her/his inability to communicate with the public (or chooses not to communicate with the public at all) that means that there may not be any other source of information the public can access to understand the science.

These barriers to information reaching the public are likely to have an effect on the public's "science literacy." In the case of science communicators (or at least science journalists), practitioners can play a role as *gatekeepers*, filtering through information before it reaches the public (Polman et al., 2014). Understanding the theoretical framework of gatekeeping, both at the institutional and individual levels, helps illustrate the information that the public ultimately receives.

Gatekeeping and science communication

Gatekeeping determines which stories (and in the case of science communication, which sciences or technologies) are covered and allowed into the public sphere (White, 1950; Singer, 2001; Soroka, 2012; Deiuliis, 2015). Broadly speaking, gatekeeping is a process of deciding what information is released to the public, as well as how information is displayed or organized (Barzilai-Nahon, 2008; Deiuliis, 2015). Gatekeepers are individuals, or organizational pressures, that stop or allow the "flow" of information from the source to the public (White, 1950). Part of this process is that people naturally organize and prioritize incoming information (Tuchman, 1973). Similarly, communicators receive information about potential stories, then organize and prioritize it, based on personal or organizational biases (Tuchman, 1973). There are four levels, or factors, that influence gatekeeping: organizational factors (or the organization's leadership, determined priorities, the cost of production and available time/resources), story factors (which are, in part, determined by news values – but also by the type of story, how easily it can be interpreted and audio-visual features of the story if presented in a video and/or audio format), and extra organizational factors (which is focused mostly on the individual communicator's values, background and training, or ability to write about a topic) and cultural factors – such as social systems, cultural norms and ideologies (Barzilai-Nahon, 2008).

A new challenge to the traditional gatekeeping model is the advent of the internet. The web allows content to spread out to millions of people, ignoring socio-political, economic, and geographic barriers (Singer, 2001). Yet even in the age of the internet, news organizations and practitioners must often decide what is covered and what is not as part of the gatekeeping process (White, 1950; Singer, 2001; Polman et al., 2014).

Gatekeeping in the digital age presents a series of dilemmas, however. The Internet is often an unreliable gatekeeper (Polman et al., 2014). Commercial or PR messages and pseudoscience are often mixed in with credible research is search results (Polman et al., 2014). Sites can be made to look more credible or site owners can purchase (or manipulate) top spots on search engine results (Polman et al., 2014). At the same time, journalists seem willing (and are, to some degree able) to abandon gatekeeping roles they once held as the Internet allows users to create personalized news alerts, focusing only on stories of importance or interest to the reader – which may or may not have been deemed important or newsworthy before the Internet (Singer, 2001).

As for science communicators the challenges of “keeping up” with the latest advances in the field, gatekeeping is relevant because it is considered to exist on three levels within science communication. First, the scientist(s) is a gatekeeper. They possess the knowledge that the communicator wants/needs. The scientist(s) acts as the first “gate,” deciding which knowledge and information to give, how to give it, and what to withhold. The second gate is the communicator’s own ability to understand science. This may come from a necessary knowledge base (or lack thereof), or an (in)ability to grasp certain concepts and ideas. The third gate is the communicator, who decides which knowledge to pass along to their audience(s) – or in the case of PR professionals, which medium the information will be given in/on.

There are other gates that may influence science communication, such as institutional, personal or cultural, but this research only focuses on the scientist, the communicator and the communicator’s understanding. Ultimately, the stories that are allowed – via the process of gatekeeping – into the public sphere may ultimately influence how scientifically literate the public is.

Science literacy

Prior literature has illustrated that the public generally lacks basic knowledge about science and technology (Treise & Weigold, 2002). At the same time, there is a lack of a measure or consensus of what constitutes “science literacy” (Treise & Weigold, 2002). Majima (2015) defines science literacy as the understanding of basic science facts and concepts, as well as an understanding of the scientific process and the possession of skills necessary to critically evaluate claims. Polman et al. (2014) says that true science literacy will be reached when individuals no longer see science as a difficult or impossible to understand mess of information, but will understand science (at least in some basic way) and the purpose and impact it has on their lives.

Scientific illiteracy can cause the public, through individual actions or through their selection in leaders, to make decisions that are not in the best interests of themselves and/or society (Sinatra, Kienhues & Hofer, 2014). This lack of science literacy is important to consider; for it is not always clear when advocates or organizations (usually industry, businesses or non-governmental organizations) have shaped a science message to further their goals. Individuals are often not as aware as they should be of the agenda or true nature of the ‘science’ being presented to them (Hutchings, 2016). Non-scientists sometimes struggle to determine who is a valid and credible source of information and who is not. The Internet allows anyone to appoint themselves as “experts” and use “scientific-sounding” language to convince them to accept inaccurate and/or misleading information (Britt et al., 2014).

These conditions have led some to trust pseudoscience or “fake science” (Majima, 2015). Pseudoscience does not always have a clear break from real science, but has several defining characteristics that make it more identifiable. It makes claims that appear scientific, but lack supporting evidence from existing literature or research. Pseudoscience also provides knowledge that does not expand with experience, often relying on a single theory, rather than multiple theories like most science does. Pseudoscience lacks control samples, uses obscure language and a lacks an evaluation of existing theories (Afonso & Gilbert, 2010). People who are vulnerable to pseudoscience often have a poor understanding of the nature of science and/or have pre-existing belief-biases that restrict them from critically assessing the content (Afonso & Gilbert, 2010).

Even a level of scientific literacy does not completely eliminate the problem of accepting pseudoscience. Even scientifically literate and well-educated people can still believe the claims of pseudoscience (Majima, 2015).

To fully understand “real” science and its impact on daily life, one needs to be able to find, understand and evaluate new information (Polman et al., 2014). They also need to understand how the science or technology impacts society, culture and economics, in addition to having an understanding of the ethical complications (Polman et al., 2014). To some degree, communicators must accept that science literacy will always be limited as the public is often doubtful or mistrustful of controversial science. Limitations also exist because research is growing so fast that it’s impossible for anyone to keep up with everything that might be relevant (Jasinski, 2010).

Despite the importance of science knowledge, there is a large degree of a lack of science literacy in general society. The public does not acquire the science knowledge it needs either as a result of lack of interest, lack of coverage, pseudoscience, biased coverage or a combination of these factors. As a result, reliable and accurate science communication is incredibly vital and will continue to become more so as science, medicine and technology become more tied to everyday life. It would be unrealistic to expect members of the public to be aware of every detail of what occurs in science, even if it has an effect on them. This is the role that science communicators fill: providing relevant science information in an understandable way. Yet, science literacy (or lack thereof) is not the only issue or pressure working against science communicators.

Science communicators: Roles, perceptions and pressures

Being a science communicator takes years of practice and exemplary skill. The writer must be able to not only understand many sciences, but must be able to effectively “translate” the knowledge into words and/or images and make them accessible to those who have little or no background in science (Treise & Weigold, 2002). Science journalism, in particular, often relies on appealing to the audience’s sense of wonder/awe or focusing on the human interest aspect to get the audience interested in science (Lynch et al., 2014; Brown, 2014).

As for knowing science, most communicators learn science on the job, rather than having a science background or degree (Weigold, 2001). However, Weigold does not elaborate on *how* communicators learn science, only that they *do.* Weigold (2001) also notes that, at least among reporters, these writers often do not have backgrounds in science. Specialist reporters, who focus on science, have more education and a richer background in science and usually hold different opinions, values and ideas than more “general” reporters as a result of their exposure to science during their career (Amend & Secko, 2010).

Given this heightened specialization, how do science communicators decide what to cover? In smaller news organizations, it may fall to general assignment reporters to cover science, or they may rely on wire services, such as the Associated Press for their science news (Maier et al., 2014). Some larger organizations will have specialized reporters who focus on predominantly science-based topics. On the other hand, the PR professional’s organization often wants them to teach or explain science while promoting the organization, limiting what they are able (and allowed) to write about (Lynch et al., 2014).

For science communicators (especially journalists), there are several issues that add to the issue of keeping up with science and effectively covering it for the public, including tight deadlines, novelty and competition (Maier et al., 2014).

One issue for communicators is that only so much space (or time) can be set aside for science in any medium (Maier et al., 2014). Even if space constraints have been loosened in the age of the internet, deadlines generally remain inflexible and very short (Maier et al., 2014). Another related issue for journalists is that newsrooms are shrinking and newspapers are cutting their science pages/articles (Pinholster & O'Malley, 2006). This is a problem for science coverage because to effectively explain science news, it requires giving the audience a degree of background in the piece (Maier et al., 2014). This equates to more time/space needed to cover science and less for other news stories. Some news media are unwilling, or unable, to provide this additional time and space (Maier et al., 2014).

Novelty is another value that determines how science is covered and what stories are chosen. Things that seem strange or out of the ordinary are more likely to be covered than things that are more common (Maier et al., 2014). Even if a certain discovery or development is novel, it may not always be clear to non-scientists or communicators that it's different from all the other research being done in the same area (Maier et al., 2014). And the more people a story affects, or the more it impacts a particular group or area, the more likely it is that the story will be picked up and broadcasted (Weigold, 2001). However, it isn't always clear to communicators (sometimes not even to scientists) when research will have an impact or what that impact might be. As a result, sometimes scientists are reluctant to make claims about the impact their research will have (Weigold, 2001).

There is also competition between various media outlets to draw in audiences. Yet there is no consensus on how much competition improves (or degrades) the accuracy of science news (Andina- Díaz, 2009). Competition does potentially make it more difficult for outside organizations or government to silence or control the media, but competition may encourage media to bias their information – or put out erroneous information – to match their audience's beliefs or opinions in order to remain in business (Andina–Díaz, 2009).

For science communicators, competition to get out an article or story first may mean that communicators may make more inaccurate statements or mistakes in a publication as a result of needing to get a story out before anyone else. It may also have an impact on freelancers – if someone writes a similar story and sells it, it could be more difficult for other freelancers to sell their work. In-house writers may or may not have as much of a concern or pressure with getting a story out first unless the publication potentially has a negative impact on their organization.

In both journalism and public relations, science communicators rarely write for scientists; instead, they generally write for the public. As a result, the writing has to be created for the broadest audience possible. This sometimes requires the removal or simplification of science/ technical jargon (Maier et al., 2014). Occasionally this leads to "oversimplification" of science coverage (Weigold, 2010). Communicators may ignore or not cover parts of the research scientists think are important (such as the process of research, rather than results), while communicators write for audiences who want to know only the results and may have no interest in the process (Maier et al., 2014). Scientists often view science communication as a way of addressing gaps in public knowledge (Lynch et al., 2014).

Science is, and has been, successful in explaining technology, improving human lives and explaining the way the world works (Casadeval & Fang, 2014). As a result of the expansion of research, science has developed into many fields and subfields, each of which becomes more specialized and interdisciplinary. This raises a large problem: If scientists cannot keep up with changing trends in their own fields, how can outsiders ever hope to know what is going on with science? More importantly, how can the communicators, whose purpose is to translate science, keep up with this trend? If communicators can't keep up, how can the public, which is often affected by discoveries, hope to make informed decisions if vital information is unavailable to them?

This research will address these key questions. More specifically, the thesis will first establish: 1) who science communicators are, 2) how science communicators learn about and keep up with science; and 3) what pressures they may face in communicating science. This research will be relevant for practicing communicators because it identifies general demographics, it shows what communicators do, in general to learn about and keep up with science. Other communicators can potentially use the findings to improve their ability to learn about and keep up with science.

RQ_1: Who are science communicators?

RQ_2: What is the relationship between scientists and science communicators?

RQ_3: How do science communicators learn about and keep up with science?

RQ_4: What pressures do science communicators face?

CHAPTER 3

METHODOLOGY

Currently, there is little research available on how science communicators either initially become aware of science in order to communicate it (referred to as “learning about” science), or how they continue educating themselves about the various fields of science (referred to as “keeping up” with science). Understanding the process that communicators learn about and keep up with science may lead to better and more accurate coverage of science topics by communicators, which in turn, may expand societal understanding of science, in general.

This thesis uses a multi-method approach, combining a survey with interviews. The combination of methods was chosen because the survey enables the ability to reach a broader audience and gain surface-level information. The researcher can also receive detailed and specific information from the interviews. The survey will show generalizable information, whereas the interviews have specific details. The survey and interviews are paired together because they will generate a larger variety of information than either one alone.

Generally speaking, surveys are favored as a method because they are time efficient and allow data to be accessed quickly (or immediately) (Wyse, 2012). The instrument is accessible to virtually everyone, allowing respondents to take the survey when it suits them (Baltar & Brunet, 2012). Surveys are also inexpensive, easy to administer and independent of geographical boundaries (Wyse, 2012). Researchers can collect data from a large sample, allowing comparisons within the population (Grimmer & Bialocerkowski, 2005; Wyse, 2012; Baltar & Brunet, 2012). Electronic surveys, so long as they don’t collect or ask for emails or identifiable information, also ensure anonymity for participants (Shannon & Bradshaw, 2002).

There are some disadvantages to surveys, though. When taking the survey, there may be some confusion from respondents, as they must interpret the survey independently without the direct guidance of the researcher (Baltar & Brunet, 2012). At the same time, it may be difficult for the researcher to verify that the participant is who they claim to be (Baltar & Brunet, 2012).

This study used an online survey, which was chosen for several reasons. An online survey can be conducted very cheaply, with data easily organized for analysis (Wyse, 2012; Baltar & Brunet, 2012). For these reasons, a survey was chosen for this research.

Interviews allow for participants to draw attention to details and/or data they think is important, and allows for flexibility in that responses can be pursued more in depth (Opdenakker, 2006). In addition, interviews can lead to unexpected results or generate new ideas for further research (Leko, 2014). Interviews enable in-depth understanding of the research question and allow the researcher to gain better insights on the participant's experiences, understanding and perceptions (Merry, Clausen, Gagnon, Carnevale, Jeannotte, Saucier, & Oxman-Martinez, 2011). Interviews can also get at information that quantitative research can't, such as meanings, interpretations and personal narratives (Merry et al., 2011; Frels & Onwuegbuzie, 2013). When combined with quantitative data, interviews can enhance the results, and conversely quantitative data can enhance the results of qualitative data (Frels, 2013).

There are some disadvantages to interviews, though. Interviews can be time-consuming (Minter, 2003). Interviewers also need preparation/prior training to be effective (Minter, 2003). Interviewer error or bias (how the interview is perceived and the way they say or phrase things) may influence how the interviewee responds (Minter, 2003). Interviews are very flexible -- in what the interviewer can ask and how the interviewee can respond – but this can create inconsistencies in the data (Minter, 2003).

The interviews, despite their shortcomings, are valuable because they can go into more detail and depth than the survey on the same subjects. This allows for the research to not only examine what methods are most successful, but also touch on why those methods are successful. For other questions, such as the politicization of science, it can do the same thing, looking at responses more in-depth.

This research was submitted to the Iowa State University Institutional Review Board as an “exempt study,” as it did not involve vulnerable populations, and because personally identifiable information was not collected or used. The initial IRB approval was only for the survey portion of the research. A second application to update the research to include interviews was submitted and approved as an “exempt study” as well. There were no risks to the interview participants or survey respondents, nor were there any benefits for either group. IRB documentation is accessible in Appendix C and D.

Interview protocol

The population for both the survey and interviews was science communicators – defined as an individual who has a profession of communicating science to the public, usually (but not always) with a background in a communication and/or science related field. The interviews were conducted by phone in March and April 2016. Interview participants were purposely selected from professional contacts, encompassing diverse industries including: government, university, journalism, freelance and medical writing. Invitations were sent by email to the study participants.

The interviews used a semi-formal protocol to allow the researcher to ask additional questions as needed, but ensured each participant was asked the same set of questions. The initial "interview" was a pilot test of the research questions that was focused more on making them understandable and looking for feedback. The participant was a science communicator known to an acquaintance of the researcher who was willing to provide feedback. Based on the participant's feedback and questions for clarification, the interview questions were all modified to make them clearer to those less familiar with the research. The results of the pilot interview were not included.

The survey questions generally asked about the current organization employed by, years in science communication, effective methods for keeping up with science, The full interview protocol is available in Appendix B. General themes are demographic information, observations about the current state of science communication and predictions about the future, how they learn about and keep up with science, the specialization of science, and an open-ended question that allowed interviewees to bring up any other points they thought were important.

The researcher took notes during the interviews. Prior to beginning questions, the interviewer stressed the importance of not mentioning any personally identifiable information when answering questions. Upon completion of the interview, all interviews were also recorded and transcribed. To maintain anonymity of participants, subject names and institution name were not recorded. (There was one instance where the participant mentioned the name of their institution. This was not included in the transcript). Each participant's transcript was assigned a unique number that was not associated with the study subject's identity.

After completion of the interviews, the transcripts were analyzed. The researcher began by making a list of key points made in each interview. The lists were examined for themes that were brought up by at least three participants. The process of integrating the study's key themes relied upon grounded theory, which suggests that data is created and modified through interactions with participants (Creswell, 2007). Grounded theory suggests that the examination of past experiences and knowledge can be used to generate new hypotheses and knowledge (Heath & Cowley, 2004; Creswell, 2007). It is an effective method for studying interactions, processes or actions that involve many people or individuals (Creswell, 2007).

The interview questions and survey questions were built together with slight differences in wording. However, some interview questions were then used as a framework for the survey questions. The question about the politicization of science in the survey, as was the the questions about the willingness and eagerness of scientists to talk to communicators were added to the survey because both points were mentioned by several interview participants.

Survey protocol

To distribute the survey, a snowball sample was used. A snowball sample is one in which those initially contacted to take the survey are encouraged to forward it to those they may know, and the new participants are also encouraged to send it on (Baltar & Brunet, 2012). Snowball sampling is useful when studying populations with few members, or when studying populations that are difficult to reach (Baltar & Brunet, 2012). It works well because it builds on trust and communication networks that already exist, rather than requiring the researcher to build those ties or hope that a blind contact will respond (Baltar & Brunet, 2012). However, the disadvantage of a snowball survey is that it is biased toward those who have larger personal networks (Baltar & Brunet, 2012). The survey did not ask for, or track, any personally identifiable information. Any write-in answers that may have contained personally identifiable information were edited to make them unidentifiable.

The snowball sample encompassed several professional organizations in the field of science communication. Listserv members of the National Association of Science Writers – the largest professional organization of science communicators -- received an initial email on April 10, 2016, and received a second, follow-up email on April 27, 2016. Participants were asked to both take the survey and forward it to other communicators. Using publicly available lists of members, the survey link was also distributed to members and/or leadership posts of: the Council for the Advancement of Science Writing (CASW), the Science Writer's Handbook, the Society of Environmental Journalists (SEJ), Chicago Science Writers, the Hawaii Science Writers Association, the Council of Science Editors, the American Medical Writing Association, Association for Communication Excellence in Agriculture, Natural Resources and Life Sciences, Association for Healthcare Journalists, the New England Science Writers, the DC Science Writers Association, the World Federation of Science Journalists (WFSJ) and the Philadelphia-area Science Writers Association. These organizations were selected from a Google search for "science writing organizations" or from recommendations from professional contacts. The organizations were emailed and asked to send the survey link out to their members. They were also asked to encourage their members to send the survey out to other science communicators.

The online survey was programmed into Qualtrics in March 2016. A pretest of the instrument was conducted on April 6, 2016. The pretest was conducted to make sure the survey was available to people, and to see if there were any responses individuals might accidentally skip. Of the 19 participants who took the pretest, the only issue identified was that the response categories for the methods of learning about and keeping up were flipped (learning about started at “very effective” to “somewhat effective,” then ended with “very ineffective.” The keeping up question was the reverse; it started with “very ineffective” to “somewhat ineffective” and ended with “very effective”). This question was altered.

After the pretest, there was a “soft” opening of the survey on April 7, 2016. The survey instrument was sent to a small number of participants before launching the entire sample – a precaution in case the survey instrument had any problems. On April 10, 2016, the survey was heavily promoted in social media and placed on several listservs. The researcher also began conducting members of science organizations directly in this period.

The survey had 31 questions with three filter questions. The first filter asked respondents if they were willing to take the survey. Those who indicated “yes” were allowed to move on. Those who indicated “no” were sent to the end of the survey, and their responses were not recorded in the sample. The second filter asked about the science communicator’s current profession. Those who indicated they were not employed in communication were sent to the end of the survey, and their responses were not recorded in the sample. The final filter question asked if respondents were supervisors in their organization. The next question – asking about availability of resources – was worded in two different ways. Those who indicated “yes” to being supervisors were asked if they had adequate resources to *give* their employees/workers for them to be effective in communicating science. Those who indicated “no” to being supervisors were asked if they *received* enough resources to be effective, and were asked an additional question about how much encouragement they received from their supervisor. After the supervisor filter questions, all respondents were redirected to the same questions on the survey.

There are two types of questions asked in a survey: factual questions that asks for more precise measures and attitudinal questions that are about personal beliefs, opinions or perceptions and are difficult to measure objectively (Gonyea, 2005). This survey asked a mix of the two questions. The survey had three basic sections: demographics, general information about day-to-day routines and questions designed to assess how science communicators learn about and keep up with science. General information questions were generally multiple choice, multiple selection or write-in. Likert scales, a self-reporting measurement that assumes that each option is an “equal distance” from the options on either side, allowing for more accurate measurements, were used for several questions (Wakita, Ueshima & Noguchi, 2012). For example, when asked about the effectiveness of methods for keeping up, respondents were able to choose the effectiveness of each presented method as: “very effective,” “somewhat effective,” “equally effective or ineffective,” “somewhat ineffective,” and “very ineffective.” The survey also included a write-in portion with an open-ended question for participants. Similar to the interview data, the comments added were analyzed for recurrent themes.

After the survey was closed, responses were looked at and either kept or discarded; those who indicated they were not employed in a communication industry and those who did not complete the survey. The remaining 161 respondents were employed in a communication field and completed the survey.

Data from Qualtrics was analyzed in SPSS. First, frequency counts were examined on all variables (with the exception of write-in responses such as age and years in science communication). Several crosstabs and correlations were run, as well as linear regressions to see the relationship between variables. For the interview data, transcripts were analyzed, with the researcher looking for common themes within each interview. Themes brought up by multiple participants were analyzed and interpreted, and themes that matched (or contradicted) interview data were compared as well.

CHAPTER 4

RESULTS

Survey demographics (RQ_1)

For the survey, there were 234 respondents, with 161 completed responses. All incomplete survey responses were discarded, and not incorporated into the dataset. The data analysis only reflects individuals who answered all questions, with the exception of any write-in responses. According to the survey results, the profile of an "average" science communicator is a Caucasian female between 30-50 years old with a master's degree. This individual typically works as a freelancer or at a university. Of all survey respondents, females accounted for more than half (55.3%) of participants, while only 34.2% of respondents were males. (10.5% of respondents declined to indicate their gender). 48.5% of participants had a master's degree, 27.3% held a bachelor's degree. 21.1% held a Ph.D. and only a small portion (3.1%) held a technical or professional degree. Of study participants, 83.2% labeled themselves as Caucasian. Other participants identified as Asian (1.9%), Latino/Latina/Hispanic (1.9%) or Other/Mixed race (1.2%). (Nearly one in 10 (11.8%) respondents declined to answer this question). The vast majority of respondents (83.9%) were from the United States – reflecting the membership of NASW and other science communication organizations that constructed the study's snowball sample. Only 6.1% of the total respondents were located outside the United States. The average age of participants was 50.5 years old (SD = 14.5).

Though years spent in the field is not necessarily an indication of the depth of knowledge or experience, the survey respondents appear to be experienced science communicators practitioners, with an average of 15.8 years of experience (SD = 11.4). As shown in Table 2,

Table 1. *Demographic Breakdown*

Variable		**Frequency**	**Valid Percentage**
Gender	Female	89	55.3
	Male	55	34.2
	Prefer not to say	17	10.5
Location	United States	135	83.9
	Prefer not to say	16	10
	Europe	4	2.5
	Canada	2	1.2
	Mexico	1	0.6
	South America	1	0.6
	Europe	4	2.5
	Asia	1	0.6
	Australia/New Zealand	1	0.6
Education	Master's degree	78	48.5
	Bachelor's degree	44	27.3
	Doctorate	34	21.1
	Technical/Professional	5	3.1
Ethnicity	Caucasian	134	83.2
	Prefer not to say	19	11.8
	Asian	3	1.9
	Other	3	1.9
	Latino/Latina	2	1.2

N=161

these respondents also work across a variety of communication fields. (For ease of data analysis, the original categories of professions from the survey were merged together, creating new categories). Freelancers were the most common respondent (33.5%), followed by participants who worked for a university (29.8%), and PR/private institution/non-profit (10.6%). Retired communicators made up the smallest portion of the sample (1.9%).

Table 2. *Frequency counts of Organization currently employed by*

Variable		**Frequency**	**Valid Percentage**
Organization	Freelance	54	33.5
	University	48	29.8
	PR/Private/Non-profit	17	10.6
	Legacy Media	12	7.5
	Government	10	6.2
	Digital Media	9	5.6
	Other	8	5
	Retired	3	1.9

N = 161

Respondents covered a large spectrum of sciences in their current positions. The most common category of science covered were the Life Sciences (such as biology, botany, genetics, ecology, pathology, neurobiology, toxicology, zoology, etc), encompassing nearly three in four survey respondents (73.3%). The next common fields of science communication covered by respondents included: Medicine and Health (62.7%); Physical Sciences (such as chemistry, geology, physics, astronomy, etc.) (59%); Computer Sciences/Technology (41.0%); Applied Sciences (various engineering fields) (39.8%); Social Sciences (such as anthropology, communication studies, history, linguistics, political science, psychology, etc.) (35.4%); and Mathematics/Statistics (25.5%). (It should be noted that respondents were able to choose more than one category of coverage).

Within their organizations, the majority of media organizations (40.5%) have only one science communicator. 26.1% of survey participants worked in places with 2-5 communicators. 10.5% worked in organizations with 21–50 communicators; 9.2% were one of 11–20 communicators; 8.5% worked with 6–10 communicators; and 5.2% worked with 50 or more communicators. Across all organizations, 67.5% of respondents did not have a supervisory role within their organization, with 32.5% holding supervisory positions.

Interview demographics (RQ_1)

Of the study's interview subjects, two of the participants were women and three were men. The educational background of the subjects varied; one participant had a bachelor's degree in biology, one had a bachelor's in general science and three did not have science-related degrees. Four participants were from the Midwest and one participant was from the Northeast. For interviewees, the average number of years worked in science communication was nearly 20 years. At the time the interviews were conducted, the interviewees were employed as: a state government employee, a university employee, a freelance, a journalist and a medical writer. Before working in their current position, all interview participants had prior experience in other media.

None of the communicators interviewed described their role as a science communicator in a similar way. One participant described their role as a "translator" and another described it as being an "interpreter." Other communicators described their roles as being as bringing science to the public who may not otherwise come across it. Another interviewee described their role as benefiting the public by helping them as a storyteller follow and understand changes that are relevant to them in their daily lives. An interviewee said:

> Simply reporting some new study isn't all that important anymore. Our contribution is to tell the story around that study -- find the context, find the reason that it's going to matter to someone and find creative ways to address it.

According to interview participants, the overall amount (and potentially quality) of science reporting has declined across all industries. Every participant particularly mentioned the decrease in the production of science communication stories in traditional news media, especially newspapers. According to an interview:

> To some degree the news media has become more concise. There's not the in-depth reporting there once was. And now people have literally thousands, if not millions, of different news sources at their fingertips.

Another study participant agreed, stating: "I think of all the elements of journalism it's been marginalized just because newspapers are cutting science sections and there fewer news outlets that publish science." Even though every participant agreed that newspapers especially are on the decline, interviewees anticipated growth in several areas of science communication including in-house, independent and non-profit communication.

The relationship between Scientists and Science Communicators (RQ_2)

One aspect of science communication that was looked at was the relationship between scientists and communicators; as scientists may be the only source of information about a topic, it is important to understand how scientists and communicators get along, especially as the literature generally portrays a negative relationship.

Relationship (Survey, RQ_2)

In the survey, the relationship was defined as how easy or difficult it was for communicators to get in contact with scientists and how willing and eager scientists were to talk to communicators. Participants were asked about the extent to which they agreed or disagreed that scientists were difficult to reach as sources. Scientists seemed to be willing to serve as sources for communicators, according to survey respondents. 93.4% of survey participants said that scientists were “almost always” willing or willing “most of the time” to assist with the content production. While scientists seemed *willing* to talk to communicators, they did not seem as *eager* to speak with practitioners, based on survey results. 18.9% said scientists were “almost always” eager to talk with communicators. 52.7% of respondents said scientists were eager “most of the time” to talk, and about half that many (27%) indicated scientists were “sometimes” eager to talk to them. The open-ended data from the survey also raises the possibility that there is some degree of reluctance on the part of scientists to engage with science communicators. As one participant wrote:

> Some scientists fear misrepresentation in the media, so are hesitant to speak to communicators outside their organizations. I think it’s important for scientists to be

> trained in speaking about their research in terms the general public will understand without feeling like they are 'dumbing down' their work.

Several survey participants argued against scientists – or their organizations – being involved with communicating directly to the public.

In the survey's write-in section, one area of disagreement in the comments encompassed if scientists – and their institutions or universities – *should* communicate with the public. One survey participant wrote:

> Science communication should not be conducted by people who are immersed or trained in science. Scientists, whether they admit it or not, are biased. Science communication is better when conducted by the media/journalists because they are trained to be objective.

Relationship (Interview, RQ_2)

Interview participants stressed the importance of developing strong, positive relationships with communicators and some of the pressures they (and communicators in general) face in effectively communicating science.

Interviewees developed relationships with researchers/scientists, regularly talking to them. "I've developed a lot of relationships with a lot of the scientists because I've interviewed them in the past, and I feel like I can talk with them and ask them 'what exactly does this mean?' if the complexity is too great and/or I don't have any background knowledge," one interviewee said. Another interviewee highlighted this point, stating: "A lot of it starts with the interviewing researchers and research teams and having them explain it the way they would to their neighbor." Another participant said that:

> I am kind of big on just the power of personal relationships. I spend a lot of time talking with scientists and talking to them about what they're doing, and not just what they're doing, but what excites them about what they're doing, talking about what might be going on in other research institutions that's related to what they're doing. Sometimes we talk about issue and policy things related to science, because sometimes it is kind of a way to broaden your concept of what's going on out there. There's really a limit to what you accomplish unless you're willing to collaborate with other scientists that can help you towards your goal.

Science communicators – especially those in public relations – said these relationships often led to more accurate reporting. According to an interviewee: "We go through a process where we draft a news release – or something similar - and run it back by the source for review and approval. That process really contributes to the education and enhances our understanding of the topic."

Learning about and keeping up with science (RQ_3)

The second research question looks at the sources and methods communicators most often use and rely on to become aware of and educated about science. "Learning about" science is the process by which a communicator becomes initially aware of a topic. "Keeping up" is the process by which the communicator educates her/himself about the topic to effectively communicate it. The interviews and the survey looked at how communicators did both.

Learning about and Keeping up with Science (Survey, RQ_3)

Overall, communicators surveyed tended to rate their own understanding of the science as “average” (41.9%) or “greater than average” (35.1%). 20.3% rated their understanding as “very good” (above “greater than average”).

Science communicators use a variety of methods to remain up-to-date and educated about science in general. When it comes to *learning about* science, there was no method that was not considered universally effective by survey participants. Of the respondents, 77.6% considered that learning about developments directly from scientists was either a “very effective” or “somewhat effective” method. Survey respondents also viewed journal articles as effective, with 75.8% considering the practice “very effective” or “somewhat effective.” The internet as a source was considered slightly less successful with 65.2% ranking it as “very effective” or “somewhat effective” as a method to learn about science.

Keeping up with science, on the other hand, is the process by which communicators maintain their knowledge over time. Similar to learning about science, the most effective method chosen by respondents for keeping up with science was talking directly to scientists, with 78.3% selecting it as “very effective” or “somewhat effective.” Journals and articles were listed as “very effective” or “somewhat effective” (73.9%), while 72.7% of respondents found the internet “very effective” or “somewhat effective.”

Table 3 *Frequency counts of Methods used to Learn about Science*

Methods for Learning about Science						
Method and Effectiveness (%)	Very effective	Somewhat effective	Equally effective or ineffective	Somewhat ineffective	Very ineffective	Not applicable
Coworkers	16.1	34.2	11.8	5.6	2.5	29.8
Journals/Articles	43.5	32.3	6.2	3.1	1.2	13.6
Conferences	34.8	33.5	9.3	2.5	8.1	19.9
Scientists	44.7	32.9	8.1	1.2	0.6	12.5
Social Media	20.5	32.9	14.3	9.3	3.7	19.3
Online/Internet	29.2	36.0	13.7	1.2	1.2	16.2
Press Release	15.5	36.6	20.5	8.7	3.7	14.9
Interest Group	6.8	31.1	18.6	9.3	5.0	29.1

To examine potential association between variables in both learning about science and keeping up with science, additional tests were run to determine the extent to which variables predicted outcomes. Multiple regression enables the researcher to determine the relationship between multiple variables, while also picking out which variables had the strongest independent influence. Several regression models were tested to assess how demographic variables predict the ability of respondents keep up with science. To test the correlations, the following variables (years at position, years in science communication, perceived pressure, education, gender and organization) were used to assess how well the communicator perceived their ability to learn about or keep up. None of the tests showed any statistical significance.

Table 4. *Frequency counts of Methods used to Keep up with Science*

Methods for Keeping Up						
Method and Effectiveness (%)	Very effective	Somewhat effective	Equally effective or ineffective	Somewhat ineffective	Very ineffective	Not applicable
Coworkers	16.8	32.9	13.7	7.5	1.9	27.3
Journals/Articles	40.4	33.5	8.1	2.5	3.1	12.4
Conferences	36	30.4	10.6	1.9	1.9	19.3
Scientists	52.2	26.1	6.8	2.5	1.2	11.1
Social Media	25.5	27.3	28	8.7	6.2	14.3
Online/Internet	40.4	32.3	12.4	3.1	1.9	9.9
Press Release	18.8	40.4	18	8.1	1.9	19.8
Interest Group	8.1	26.7	19.9	8.9	6.8	29.8

N = 161

Both keeping up and learning about science have an additional pressure attached to them; namely that, as science becomes more specialized, or at least as the body of knowledge grows, it means that communicators, especially new ones, must put more and more effort into keeping up with science. Specialization potentially creates more work for science communicators in their attempt to keep up with science. More complex sciences, or more specialized sciences, require communicators to learn more background information to fully understand a science. 72.7% of survey respondents indicated that specialization in science was happening “a lot.” Participants were also asked about how much (or little) science was being politicized or made into divisive political issues. This divisiveness also potentially makes it more learning about and keeping up with science difficult for communicators. Respondents were asked to what degree they believed science was becoming politicized. 47% of respondents said it was becoming at least "somewhat politicized."

Learning about and Keeping up with Science (Interview, RQ_3)

To science communicators, learning about and keeping up with changes in the field is incredibly difficult. According to an interviewee:

> It seems like by the time I learn something new, something else has come along and made it obsolete. It's interesting to see that happening, but it does present a challenge where you have to focus on what you need to learn next.

Aligned with the survey, interview subjects identified several strategies to keep up and learn about science, including talking to scientists and reading journals and current works in the field. Results indicate that interview participants, like survey participants, are predominantly learning about and keeping up with science through direct contact with scientists or their articles and other publications. "I'm constantly interview scientists as well as reading papers are articles and I'm asking questions. I've developed a lot of relationships with a lot of the scientists because I've interviewed them in the past and I feel like I can talk with them."

In addition to scientists, science communicators seem to rely upon their colleagues in the field to learn about and keep up with science. "Increasingly I depend on other good journalists who are in certain niche areas in order to not just keep up with the latest findings but try to identify trends," one interviewee said.

Other less common methods of keeping up identified by interviewees included: using the internet, attending conferences (particularly the AAAS), regularly attending graduate-level seminars about various sciences, reading science journals and articles and reading the work of other science communicators. Others followed press releases from professional organizations. “Some of those embargoed study lists [contained in press releases] are better than others,” an interviewee said. “Some could do a better job of highlighting things that are really newsy rather than burying their lead.” Even with these methods, it is difficult for the interview participants to keep up with everything. “At a certain point you have to accept that you can’t keep up with everything and instead work on your strengths and use editorial judgment to determine what’s important to keep up on,” another interview participant said.

Specialization makes keeping up even more difficult. As science becomes more complicated and specialized, it likely means that a communicator must know even more background information to fully understand the science. Even if science is not becoming more specialized, but more interrelated, as one participant said, it means that communicators must have background knowledge in more than one science. Four of five participants agreed that science was becoming more specialized in all fields of science communication. According to an interview: “You don’t meet very many researchers anymore who say ‘I’m a physicist. People say ‘I’m a condensed matter physicist specializing in crystallography.’ The disciplines get a little more hair split as we discover more avenues to research.” This specialization can present a huge challenge for reporters, especially. An interviewee said:

> Reporters tend to be more generalists. What happens then is you may be dealing with journalists who don’t have expertise in a certain area because they’re required to cover a variety of topics rather than specialize. That’s one of the challenges for PR people in

science/medical health; they have to realize they're not dealing with an expert, which enhances the importance of being able to communicate in layman's language.

One participant disagreed, however, that science was becoming more specialized. "I see that there's a greater role for team science and integration and collaboration," the interviewee said. "I think it means the sciences are coming together and broadening in new ways." Despite this view, the general consensus of interviewees asserts that there is increased specialization in the field.

Interview subjects also agreed that science communication was growing increasingly politicized. As one subject said:

> The most striking and probably frustrating change I've seen [in science communication] is the political polarization of science. The tendency increasingly is for people to view information that they receive with highly attuned lenses of either partisanship or ideological identification and are, in my opinion, frequently leaping past the actual science and towards the ways the conclusions either fit with, or challenge, their preconceived notions and political ideologies.

Ultimately, such debates can impact the public's knowledge on science. According to one interviewee:

> The key is going to be who the public accepts as the credible sources. They're going to be inundated with data, and a lot of that data is going to be self-serving and support a particular position or philosophy. It's going to be a challenge for both communicators and the general public to establish who those credible sources of information when it comes to science are.

This challenge was echoed by other interviewees:

> It's challenging to explain complex issues to the public without getting into the background and the more you do, the easier it is to lose your audience simply because they're not prepared or willing to get into it.

Pressures on science communicators (RQ_4)

The first research question addresses the pressures on science communicators, which are likely to have an influence on the way they approach, understand and cover science – including how they learn about and keep up with science. Science communications face several pressures, including: politicization and/or specialization of science, availability of resources, and ability to get in contact with scientists. Understanding these pressures is important because it likely has some influence on how science communicators go about learning and keeping up with science.

Pressures (Survey, RQ_4)

Even when a communicator has access to, or acquires information, there are other pressures they face. One of these pressures is getting stories out first.

In assessing the level of competition in the industry to get stories out first, 77.7% either "strongly agreed" or "somewhat agreed," 12.4% "neither agreed nor disagreed," and 5.6% "somewhat disagreed" that there was pressure to be the first to release stories.

Another pressure on science communicators is the internal pressure related to concern about making mistakes.

68.2% of participants indicated that they “strongly agreed” that they were concerned with making mistakes when writing about science, while 18.8% indicated they “somewhat agreed” that they were concerned about making mistakes. When mistakes did happen, communicators generally placed the blame on themselves (69.6% of all respondents) rather than the experts (45.3%) or the institution/organization they are currently employed by (16.8%). For survey participants who blamed scientists for mistakes, 89% found scientists willing to talk to them “almost all the time” or “most of the time.”

Pressures (Interviews, RQ_4)

Other competitive pressures were also identified in the interviews. One pressure was that, beyond getting stories out first, sometimes it’s difficult to get stories out at all. Traditionally, legacy media acted as a gatekeeper and challenger for PR practitioners to disseminate their press releases. However, as legacy media downsizes and loses influence, it makes it both harder for PR practitioners to get out their messages, while reducing the ability of Legacy Media to challenge inaccuracies in press releases. “A lot of these traditional ways that organizations like mine got their information out, like through press releases, they aren’t as relevant anymore and don’t get as much penetration,” an interviewee said.

There are also new pressures emerging that science communicators have to face, beyond the traditional competitive pressures. For example, one participant brought up an issue related to geography; it’s harder for some areas of the country to get science coverage. Specifically, the interviewee mentioned the “coastalization” of news where, increasingly, journalists are only covering scientific advances from the Northeast and West coasts of the country.

"I think what this means for science journalism is we're likely to see people covering science increasingly out of touch with audiences that don't happen to be on the coasts," an interviewee said. Science communicators also indicated they felt pressure to make an impact, particularly on the public's ability to understand science. According to one interviewee:

> What's journalism for? That's an important question to ask. If it's not attached to a measurable model of impact on social change then what's the point of it? On that count, we're failing. Just look at the state of basic research survey results from Gallup or Pew regarding what people think about basic science issues. Clearly, we're failing. We're doing great work, but we're not having an impact. So there's something wrong.

Views on the future

Despite the pressures faced and the challenges of both learning about and keeping up with science, three interviewees stated that science communication will continue to become more important. A similar number of participants stated that the public's interest in science will continue to increase over time. However, another participant stated that, "People are looking for instant results in science, and a lot of times it isn't like that." In a similar vein, one participant stated:

> It seems like people's attention spans are getting shorter. It becomes more of a challenge to deliver complex scientific ideas in ways that are catchy and still fun, but still get the important information across. Even though I think the internet has made people's attention spans shorter and it can be more difficult to capture their attention, on the other hand, the internet has also given us a sort of renaissance of long form journalism.

Another interviewee highlights this struggle:

> I think some people have kind of given up on trying to bridge the divide and in our more fractured media landscape; there are sufficient audiences for some outlets to focus on those who agree with them. In fact, the more outrage they can provoke within that groups and the more clicks they get, the better their stories perform. So there's, somewhat counter-intuitively, less incentive for science reporters of a certain ilk to make their materials acceptable to, or read by, a broad spectrum of people and instead focus on people they know will agree on a particular case. That leaves those of us who are trying to bridge the divide to wrestle with that.

Despite the challenges facing science communication, most participants remained positive about the importance of science communication in the future. "There's a lot of science that ties into energy and the environment that's going to become more vital as we proceed," an interviewee highlighted. "I don't see science communication ever becoming less important."

CHAPTER 5

IMPLICATIONS AND CONCLUSIONS

The survey and interviews looked at three main points: the pressures science communicators experience, how they learn about (or become aware of) new topics in science and how they keep up (or educate themselves about science to effectively communicate it to non-specialists). The relevance of this study is that it: 1) provides a 'snapshot' of what the demographics of science communicators currently look like and 2) it begins to unveil the challenges within the process by which science communicators transfer information from scientists and to the public (or non-specialist audiences). The findings of this research can inform communication practices to improve both the communicator's ability to learn about and keep up with science, but also the quality of information presented to the public.

It seems that science communicators have, and do, cover every science imaginable. The research seems to indicate that science communicators use any methods at their disposal to learn about and keep up with science, regardless of the pressures they must work against. They are very concerned about making mistakes and feel there is a moderate to large degree of pressure to be the first to publish material about a science topic.

The interviewees consistently brought up the point that traditional media is declining and/or trying to adapt to the new mediums available. The resources available to these industries is declining, forcing reporters to cover more as staff are cut – making it harder to effectively keep up with science, or any topic. This decline of legacy media (or the way it's transitioning into something new) may also be leaving the public without an objective voice that can point out and correct science inaccuracies presented by those who have something to gain by presenting inaccurate information. Yet communicators seem to view the future of science communication, despite the pressures they face.

The relationship between scientists and communicators

In both the survey and interviews, most communicators seemed to be able to get in contact with scientists/experts without too much difficulty, indicating that scientists were willing, to some greater or lesser degree, to talk to them. These preliminary findings suggest that science communicators are effectively able to reach the scientists and experts in order to effectively write about science. This addresses the first gatekeeping level; the scientist, as the source/generator of knowledge, is willing to let the knowledge out to communicators. If knowledge is allowed out to the communicators, it is also, indirectly, allowed out into the public as well. This generally positive relationship between scientists and communicators is a very positive indication that both groups want the public to have access to science information and are willing to work with each other to accomplish that goal. This may also indicate a favorable current relationship between scientists and science communicators. This finding may indicate that the relationship may be more positive than identified in prior studies. However, most prior studies looked only at journalists while a large proportion of the respondents for this research's survey were employed by universities who are colleagues with (or work for) scientists.

Learning about and keeping up with science

Surprisingly, there were no methods that stood out as being significantly more or less effective in learning about science. The most effective method of learning about science, regardless of any other factors involved or correlated, was talking to scientists to learn about science stories. As previously stated, this could mean that communicators are very effective at building generally positive relationships with scientists. Reading journals/articles was also viewed as very effective, which could mean that communicators are very active in searching out science-related stories to write, relying on science journals to keep them up-to date on possible stories. In short, the most effective methods for learning about and keeping up with science involve reliance on scientists either through in-person (or electronically assisted) communication or through their reading their writings in journals and articles.

Like learning about science topics, communicators are using every tool available to them to make sure they are well-educated enough about a science topic to accurately write about it. To keep up with science, scientists were listed as the most effective method of being sufficiently educated about a science topic in order to cover it. This possibly means that, again, communicators are working to build positive relationships with scientists, who then help educate them. In interviews, multiple respondents mentioned that they were more successful if they had built positive relationships with scientists and experts.

The increased specialization of science is one area that respondent opinions in both the interviews and survey generally matched. The majority of interview participants and survey respondents indicated that specialization is happening to a large degree, while a few disagreed. This general agreement may mean that science communication will become more difficult for practitioners, not only because science is branching out but also (as some interview participants mentioned) science is becoming more collaborative and overlapping. The ability of communicators then to keep up with such a large spread of sciences becomes even more important to look at and understand as sciences continue to expand.

When it came to (perceived) politicization of science, most survey respondents answered that there was moderate to strong degree of politicization occurring within the field. Interview subjects seemed to feel this pressure more strongly. It seems, then, that there is some degree of politicization occurring in science (or at least is perceived to be), but the exact degree is not totally agreed on. And some sciences, as stated in the interviews, are likely to be more politicized than others. Despite this, and other issues, interview participants were hopeful and positive about the future of science communication.

Based on the results of the research, science communicators should be able and willing to use every tool at their disposal to learn about and keep up with science. Most notably, communicators should be very proactive about developing strong, positive relationships with scientists and researchers, and should subscribe to various science publications within their areas of specialization. Supervisors should, if possible, ensure that their employees do have adequate resources to keep up with science if they want it to be effectively covered, and should also work hard themselves to keep up with the science their communicators are covering to reduce the chances of mistakes occurring.

Impacts on the general public

The decline of coverage and resources in traditional media, as identified by interview subjects, may lead to the ability of those in the political arena – and those with personal interests – to skew the results of research to fit certain viewpoints with near impunity. As the number of available sources of science information increase due to the Internet, it will become increasingly difficult for the public to sort through which sources of information are reliable and which are not. This is another form of gatekeeping; for the public must choose to accept the information provided by that source. The combination of all these issues (the decline of traditional media, the increased politicization of science, the decline of "watchdog" journalism, the increase in available information sources, and the "coastalization" of science) may indicate a difficult future for science communicators. Not only will they have to explain science to non-specialists, they may have to counter misinterpreted science put out by political or interest groups.

Future Research

Future research has several areas to review. As scientists were not surveyed, it is difficult to assess the relationship between science communicators and their sources, or how scientists feel about the portrayals of their research, more generally. For this, scientists would have to be surveyed (or preferably, interviewed) about how they perceive: the coverage of their research their concerns and their relationship with communicators. Beyond these relationships, more research should also be conducted on several areas involving resources given or provided to science communicators. Communicators and supervisors should be surveyed about their available monetary resources, as well as time available to learn about and keep up with science.

The time it takes to go through the entire process of writing a good, mistake free and accurate science story is something else that should be studied. The work could provide insight on how long it takes to write a good science story and how much a communicator can realistically be expected to do. Future studies also could examine how science communicators reduce or avoid mistakes by surveying communicators about common mistakes they make, and what methods, practices, and/or safeguards they have in place to reduce or eliminate mistakes. Finally, future research should look at the degree to which science has been taken into the political arena and the consequences of this action not only for communicators but for the perception of science by the public.

Limitations

The sample was predominantly university employees and freelancers, which may not be representative of all science communicators. This is likely the result of relying on the listservs of science writer organizations like the NASW and CASW, which have high numbers of freelancers. University employees and freelancers may have also been more likely to pass along the survey as well. The study sought to remedy the overrepresentation of perspectives in the survey by integrating qualitative interviews with a wide range of science communicators. The interviews intentionally had a more equal representation of various industries (freelance, university, government, journalist and medical writing). Despite this fact, with the underrepresentation of legacy media, and other communicators such as PR professionals, the survey’s snowball sample cannot be taken as being representative for all science communicators. As the interview and survey are self-reported, the results may or may not be an accurate reflection of how communicators learn about or keep up with science. In addition, the survey asked three questions related to the ease of contact, willingness and eagerness of reaching scientists, and used them to determine the relationship between scientists and communicators. These variables were only potential indicators of a relationship. Because these questions are not directly asking about perceived relationships (i.e. how do you perceive your relationship with scientists?), it cannot be considered a necessarily accurate measure of how good or bad the relationship is. The use of “learning about” and “keeping up with” may have been confusing to, or misunderstood by, survey participants.

Conclusion

Science communicators are in a unique position. Science is becoming more difficult to understand for non-specialists as it becomes more complex, requiring much more education, work and research to fully understand the newest developments in science. As a result, the knowledge gap between scientists and the public may widen. Currently, science communicators do their best to span that gap. But communicators may fall behind as science expands more rapidly and grows in complexity. Even scientists can’t hope to keep up with everything going on in science. Despite the gap, there are audiences that want to know about science. Some of those who fill the gap are people who enjoy science and enjoy explaining science, but may not have a professional background in communication. With all the available sources of information out there (and with as complicated as science is), it isn’t always easy or possible for the public to distinguish between legitimate sources of science information and science that has been distorted and misconstrued to benefit someone or to cause harm. In this light, there is an opportunity for science communicators to establish themselves as valid, accurate, reliable and honest sources of information about science. This may require participation from not only the scientists, but from the public as well. Science communicators will have to find new ways, means and methods of not only explaining science, but will have to find ways to make themselves stand out and to build their reputation with both the scientists and the public.

It is important to understand how science communicators keep up with science as it continues to expand and push new boundaries at an ever-increasing rate. Often, science communicators are a vital gatekeeper between the scientists and non-specialist audiences who may not have much (if any) experience with, or understanding of, science. There are scientists who are communicators for their own work – or are communicators of science in general – but not every scientist wants to be, or should be, a public communicator. Science communicators can serve as invaluable emissaries, bringing science to the public in ways that explains how and why it's relevant to them, but can also address and bring the concerns the public has about science to scientists. By understanding how communicators learn about and keep up with science, the communicators can find the most efficient and effective methods of doing so. and improve the field of science communication.

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APPENDIX A
SURVEY QUESTIONAIRE

Q1 This research is being conducted to investigate the methods and practices used by science communicators in order to keep up with, and effectively "translate" science or other highly technical information for a non-scientist audience. It will also gain insight as to the demographics of science communicators. The primary investigator is a graduate student in Iowa State University's Greenlee School of Journalism and Communication. This research has been approved by Iowa State University's Institutional Review Board. If you agree to participate, you will be asked to respond to a series of questions that will take approximately 10 minutes. This research is intended for publication. Material would potentially be cited in academic conference presentations, in journal articles, in popular media articles and in a trade book.

RISKS There are no foreseeable risks for participating in this research.

BENEFITS There are no material benefits for participation. The researcher hopes that the research will have important insights for the theory, practice and education of contemporary communication.

CONFIDENTIALITY All survey material is anonymous, and will never be linked to your identity. The researcher will only see aggregate responses, which will be de-identified.

PARTICIPATION Please remember that your participation is voluntary, and you can skip any questions you do not want to answer. You may also stop participating in the survey at any time.

CONTACT If you have questions or comments regarding your rights as a participant in the research, you may contact the primary investigator, Brandon Hallmark (bhall@iastate.edu or 515-577-7587), or the Institutional Review Board at Iowa State University (515-294-1516).

Q2 I agree to participate in this study

Yes (1)

No (2)

Q3 What kind of organization are you currently employed by?
- ❍ Newspaper (1)
- ❍ Magazine (2)
- ❍ Digital only publication (3)
- ❍ Private Institution (4)
- ❍ Local or State Government (5)
- ❍ Federal Government (6)
- ❍ University (Public or private) (7)
- ❍ Broadcast (Radio or Television) (8)
- ❍ Non-profit (9)
- ❍ Public Relations or Marketing (14)
- ❍ Freelance (10)
- ❍ Other (write in) (11) ____________________
- ❍ Retired from these industries (12)
- ❍ I am currently not employed by any of these industries (13)

Q4 What is your position within your organization?

- ❍ Editor/Producer (1)
- ❍ Researcher (2)
- ❍ Staff writer/reporter/blogger (3)
- ❍ Other (4) ____________________

Q5 About how many science communicators are in your organization?

- ❍ One science communicator (1)
- ❍ 2-5 science communicators (2)
- ❍ 6-10 science communicators (3)
- ❍ 11-20 science communicators (4)
- ❍ 21-50 science communicators (5)
- ❍ More than 50 science communicators (6)

Q6 How many years have you been at your current position?

- ❍ Less than 1 Year (1)
- ❍ 1 - 3 Years (2)
- ❍ 4 - 6 Years (3)
- ❍ 7 - 9 Years (4)
- ❍ 10 -15 Years (5)
- ❍ 16 or more Years (6)

Q7 About how large is your publication's audience?

Q8 How many years, in total, have you worked in science communication?

Q9 What kinds of organizations have you been employed by in the past? (Places you are no longer working) Mark all that apply.

- ❑ Newspaper (1)
- ❑ Magazine (2)
- ❑ Digital only publication (3)
- ❑ Private Institution (4)
- ❑ Local or State Government (5)
- ❑ Federal Government (6)
- ❑ University (Public or Private) (7)
- ❑ Broadcast (Radio or Television) (8)
- ❑ Non-profit (9)
- ❑ Public Relations or Marketing (12)
- ❑ Freelance (10)
- ❑ I have only worked with my current employer (15)
- ❑ Other (write in) (11) ____________________

Q10 How well do feel that you keep up with changes in science and technology?

- ❍ Extremely well (1)
- ❍ Very well (2)
- ❍ Somewhat well (3)
- ❍ Slightly well (4)
- ❍ Not well at all (5)

Q11 To what extent do you agree with the following statements?

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
Other science communicators keep up well with science and technology (1)	❍	❍	❍	❍	❍
There is a lot of pressure/competition to get stories out first in science communication (2)	❍	❍	❍	❍	❍
I am concerned about getting information wrong or making mistakes in a	❍	❍	❍	❍	❍

story/article/post (3)					

Q12 When factual mistakes happen, who is usually the cause? Mark all that apply

- ❑ You or other communicators/writers (1)
- ❑ Your employer/company (2)
- ❑ The scientist(s), expert(s), or institution(s) (3)
- ❑ Other (Write-in) (4) ____________________

Q13 To what extent do you think specialization is happening in science?

- ❍ A lot (1)
- ❍ A moderate amount (2)
- ❍ Some (3)
- ❍ A little (4)
- ❍ Very little (5)

Q14 Are you a supervisor of science communicators in your organization?

- ❍ Yes (1)
- ❍ No (2)

Answer If Are you a supervisor of science communicators in your organization? Yes Is Selected

Q15 “Keeping up” is defined as any practices or methods used to understand, and write about science and technology. How much would you agree with the statement "I am able to allocate resources to allow my employees to "keep up" with science"? (I.e. If you were to send a writer to a science conference would you be able to cover the cost and give her/him time to attend)

- ❍ Strongly agree (1)
- ❍ Somewhat agree (2)
- ❍ Neither agree nor disagree (3)
- ❍ Somewhat disagree (4)
- ❍ Strongly disagree (5)

Answer If Are you a supervisor of science communicators in your organization? No Is Selected

Q16 “Keeping up” is defined as any practices or methods used to understand and write about science and technology. How much would you agree or disagree with the statement "My employer allocates resources to help me and other science communicators keep up"? (for example, if you were to attend a science conference would your employer cover the cost and give you the time to attend)?

- Strongly agree (1)
- Somewhat agree (2)
- Neither agree nor disagree (3)
- Somewhat disagree (4)
- Strongly disagree (5)

Answer If Are you a supervisor of science communicators in your organization? No Is Selected

Q17 How much would you agree with the statement "My employer (or supervisor) encourages me to "keep up" with science and technology"?

- Strongly agree (1)
- Somewhat agree (2)
- Neither agree nor disagree (3)
- Somewhat disagree (4)
- Strongly disagree (5)

Q18 How well do you think other science communicators understand science?

- Extremely well (1)
- Very well (2)
- Somewhat well (3)
- Slightly well (6)
- Not very well (4)

Q19 To what extent do you agree with the statement "It is difficult to get into contact with scientists or experts"?

- Strongly agree (1)
- Somewhat agree (2)
- Neither agree nor disagree (3)
- Somewhat disagree (4)
- Strongly disagree (5)
- I do not contact scientists or experts (6)
- I AM the scientist or expert (7)

Answer If How much would you agree with the statement "It is difficult to get into contact with scientists... Strongly agree Is Selected Or How much would you agree with the statement "It is difficult to get into contact with scientists... Somewhat agree Is Selected

Q20 How do you overcome the difficulty of contacting scientists/experts?

Q21 Are scientists and experts, in general, willing to talk to you?

- Almost always (1)
- Most of the time (2)
- Sometimes (3)
- Not usually (4)
- Almost never (5)

Answer If Are scientists and experts, in general, willing to talk to you? Sometimes Is Selected Or Are scientists and experts, in general, willing to talk to you? Most of the time Is Selected Or Are scientists and experts, in general, willing to talk to you? Almost always Is Selected

Q22 Do scientists and experts, in general, seem eager to talk to you?

- Almost always (1)
- Most of the time (2)
- Sometimes (3)
- Not usually (4)
- Almost never (5)

Q23 To what extent do you think science is becoming politicized (in general)?

- Extremely politicized (1)
- Very politicized (2)
- Somewhat politicized (3)
- Not very politicized (4)
- Not politicized at all (5)

Q24 How do you learn about new science/technology topics to write about?

	Very effective (1)	Somewhat effective (2)	Equally effective or ineffective (3)	Somewhat ineffective (4)	Very ineffective (5)	Not Applicable (6)
Co-workers or supervisor(s) (non-scientists) (1)	❍	❍	❍	❍	❍	❍
Scientific Journals/Articles (2)	❍	❍	❍	❍	❍	❍
Conferences (3)	❍	❍	❍	❍	❍	❍
Scientists or researchers (4)	❍	❍	❍	❍	❍	❍
Social media (5)	❍	❍	❍	❍	❍	❍
Online (Science websites, blogs, etc) (6)	❍	❍	❍	❍	❍	❍
Press Releases (7)	❍	❍	❍	❍	❍	❍
Interest Group Publication(s) (8)	❍	❍	❍	❍	❍	❍
Other (10)	❍	❍	❍	❍	❍	❍
Other (11)	❍	❍	❍	❍	❍	❍

Q25 Which of the following sciences have you covered?

- ❑ Physical Sciences (Physics, Chemistry, Geology, Meteorology, etc) (1)
- ❑ Life Sciences (Biology, Botany, Zoology, Human Biology, etc) (2)
- ❑ Social Sciences (Anthropology, Sociology, etc) (3)
- ❑ Formal Sciences (Statistics, Mathematics, etc.) (4)
- ❑ Computer/Technology Sciences (5)
- ❑ Medicine and/or Health (6)
- ❑ Applied Sciences (Engineering, etc) (7)
- ❑ Other(s), please list; (8) ____________________

Q26 What methods do you employ to keep up with advances in science and technology for your job? Mark all that apply and mark the effectiveness of each.

	Very effective (1)	Somewhat effective (2)	Equally effective or ineffective (3)	Somewhat ineffective (4)	Very ineffective (5)	Not Applicable/do not use (6)
Talk to co-workers or supervisor(s) (Non-scientists) (1)	❍	❍	❍	❍	❍	❍
Read Scientific Journals/Articles (2)	❍	❍	❍	❍	❍	❍
Attend Conferences (3)	❍	❍	❍	❍	❍	❍
Talk to Scientists/Researchers (4)	❍	❍	❍	❍	❍	❍
Use social media (5)	❍	❍	❍	❍	❍	❍
Go online (Science websites, blogs, etc) (7)	❍	❍	❍	❍	❍	❍
Read Press Release (8)	❍	❍	❍	❍	❍	❍
Read Interest Group Publications (9)	❍	❍	❍	❍	❍	❍
Other (10)	❍	❍	❍	❍	❍	❍
Other (6)	❍	❍	❍	❍	❍	❍

Q27 How would you rate your overall understanding of science and/or technology compared to other science communicators?

- Very poor (1)
- Less than average (2)
- Average (3)
- Greater than average (4)
- Very good (5)

Q28 What is your highest level of education?

- High School or GED (1)
- Some College (2)
- Bachelor's (3)
- Master's (4)
- PhD (5)
- Technical or Professional Degree (6)

Q29 What is your gender?

- Male (1)
- Female (2)
- Prefer not to say (3)

Q30 What is your ethnicity?

- Latino/Latina (1)
- African American (2)
- Asian (3)
- South Pacific (4)
- African (5)
- American Indian (6)
- Caucasian (7)
- Prefer not to say (8)
- Other (9) ____________________

Q31 Where are you located?

- United States (1)
- Canada (9)
- Mexico (10)
- South America (2)
- Europe (3)
- Eurasia (4)
- Asia (5)
- Pacific Islands (11)
- Australia/New Zealand (6)
- Antarctica (7)
- Africa (8)

Q32 What is your age?

Q33 Is there any additional information about science communication you want to mention?

APPENDIX B
GENERAL INTERVIEW QUESTIONS

What kind of institution are you currently employed by? DO NOT NAME

What kinds of institutions have you been employed by in the past? DO NOT NAME

And do you have any science-related degrees, and if so, what are they?

How many total years have you worked in science communication?

What are the biggest changes you have seen develop in science communication since you started?

What kind of changes and challenges do you expect to see and what do you think is the future of science communication?

Why did you get into science communication?

How do you perceive your role as a science communicator? In other words, what do you think is your primary function as you communicate science?

What kind of methods do you employ in order to keep up with science?

How effective have those methods been?

Do you agree or disagree that science in general is becoming more specialized? If you agree why, and to what degree to you think it is happening. If you disagree, why?

How easy or difficult is it for you to keep up?

What is your opinion or perception of the science communication field (where it is, where it's going)?

Any other thoughts or concerns or ideas?

APPENDIX C
INSTITUTIONAL REVIEW BOARD APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 5/18/2015

To: Brandon Hallmark
3524 Lincoln Way #80
Ames, IA 50014

CC: Dr. Jan Lauren Boyles
113 Hamilton Hall

From: Office for Responsible Research

Title: Keeping Up with Science: How Communicators Learn About Innovation

IRB ID: 15-284

Study Review Date: 5/15/2015

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

- (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey or interview procedures with adults or observation of public behavior where
  - Information obtained is recorded in such a manner that human subjects cannot be identified directly or through identifiers linked to the subjects; or
  - Any disclosure of the human subjects' responses outside the research could not reasonably place the subject at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.

The determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**

- **You must carry out the research as described in the IRB application.** Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any modifications to the research procedures (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the inclusion of participants from vulnerable populations, and/or any change that may increase the risk or discomfort to participants. Changes to key personnel must also be approved. The purpose of review is to determine if the project still meets the federal criteria for exemption.

  Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

  Detailed information about requirements for submission of modifications can be found on the Exempt Study Modification Form. A Personnel Change Form may be submitted when the only modification involves changes in study staff. If it is determined that exemption is no longer warranted, then an Application for Approval of Research Involving Humans Form will need to be submitted and approved before proceeding with data collection.

Please note that you must submit all research involving human participants for review. **Only the IRB or designees may make the determination of exemption**, even if you conduct a study in the future that is exactly like this study.

Please be aware that **approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted.**

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.